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IS 15493 (2004, Reaffirmed 2010): Gaseous Fire Extinguishing Systems--General Requirements. ICS 13.220.10



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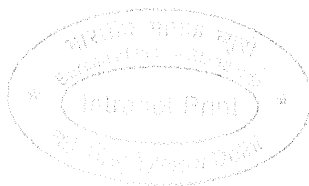
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Indian Standard
**GASEOUS FIRE EXTINGUISHING SYSTEMS —
GENERAL REQUIREMENTS**

ICS 13.220.10



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FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Fire Fighting Sectional Committee had been approved by the Civil Engineering Division Council.

Attention is drawn to Montreal Protocol on substances that deplete the ozone layer. As India is a signatory to the Protocol, country programme was drafted wherein suitable alternative clean agents have been identified in the place of Halons 1301 and 1211. As per the approved programme, this standard has been formulated for the identified alternatives. The agents covered in this standard are thus introduced in response to international restrictions on the production of certain Halon fire extinguishing agents under the Protocol signed in 1992, as amended.

It is important that the fire protection of a building or plant be considered as a whole. Gaseous clean agent systems form only a part, though an important part, of the available facilities, but it should not be assumed that their adoption necessarily removes the need to consider supplementary measures, such as the provision of portable fire extinguishers or other mobile appliances for first aid or emergency use, or to deal with special hazards.

Gaseous fire suppression systems covered in these Indian Standards are designed to provide a supply of gaseous extinguishing medium for the extinction of fire involving high value assets.

Gaseous clean agents have for many years been a recognized effective medium for the extinction of flammable liquid fires and fires in the presence of electrical and ordinary Class A hazards, but it should not be forgotten, in the planning of comprehensive schemes, that there may be hazards for which these mediums are not suitable, or that in certain circumstances or situations there may be dangers in their use requiring special precautions. These difficulties have been addressed in this standard.

Various methods of supplying clean agent to, and applying it at, the required point of discharge for fire extinction have been developed in recent years, and there is a need for dissemination of information on established systems and methods. This standard has been prepared to meet this need. New requirements to eliminate the need to release clean agents during testing and commissioning procedures are included. These are linked to the inclusion of enclosure integrity testing.

The requirements of this Indian Standard are made in the light of the best technical data available at the time of drafting this standard but, since a wide field is covered, it has been impracticable to consider every possible factor or circumstance that might affect implementation of the recommendations.

It has been assumed in the preparation of this Indian Standard that the execution of its provisions is entrusted to people appropriately qualified and experienced in the specification, design, installation, testing, approval, inspection, operation and maintenance of systems and equipment, for whose guidance it has been prepared, and who can be expected to exercise a duty of care to avoid unnecessary release of clean agent.

Specific requirements and advice on these matters can be obtained from the appropriate manufacturer of the clean agent or the extinguishing system. Information may also be sought from the appropriate fire authority, the health and safety authorities and insurers. In addition, reference should be made as necessary to other statutory regulations.

It is essential that fire equipment be carefully maintained to ensure instant readiness when required. Routine maintenance is liable to be overlooked or given insufficient attention by the owner of the system. The importance of maintenance cannot be too highly emphasized.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GASEOUS FIRE EXTINGUISHING SYSTEMS — GENERAL REQUIREMENTS

1 SCOPE

This standard specifies provisions and recommendations for general requirements, type of clean agent and their containers, container arrangement, distribution systems, such as piping, nozzles, pipe supports, alarm system, type of enclosure etc.

NOTES

1 This standard covers the general requirements applicable to total flooding clean agent systems like Halo-Carbon agents and inert gas agents. In addition, individual requirements for each type of clean agent system are covered under separate standards. Detailed design guidelines are specified in other standards. Hence before designing a protection with a particular clean agent, both the standards should be read together. Wherever there is a difference, the individual standard takes precedence.

2 This standard prescribes minimum requirements for total flooding clean agent fire/extinguishing systems. Protection with carbon dioxide is not covered in this standard.

3 Nothing in this standard is intended to restrict new technologies or alternate arrangements provided the level of safety prescribed by this standard is not diluted.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and the parties to agreements based on this standard are encouraged to apply the most recent editions of the standards indicated in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply.

3.1 Adjusted Minimum Design Quantity (AMDQ) — The minimum design quantity of agent that has been adjusted in consideration of design factors.

3.2 Approved — Acceptable to a relevant authority. In determining the capability of the installations, the authorities may base their acceptance with appropriate standards. The design and system approval shall be from national or international approving authority or lab of repute.

3.3 Authority — The organization, office or individual

responsible for approving installation or equipment or a procedure.

3.4 Automatic — Performing a function without the necessity of human intervention.

3.5 Automatic/Manual Switch — A means of converting the system from automatic to manual (manual override) and vice-versa.

3.6 Class A Fires — Fire in ordinary combustible materials, such as wood, cloth, paper, rubber, many plastics, electrical and electronic hazards without any flammable fluid or gas.

3.7 Class B Fires — Fire in flammable liquids, oils, greases, tars, oil-based paints, lacquers and the like.

3.8 Clean Agent — Electrically non-conducting, vapourizing, or gaseous clean agent that does not leave a residue upon evaporation. The word agent wherever appearing in this document shall mean as clean agent.

3.9 Clearance — The air distance between clean agent equipment, including piping and nozzles and unenclosed or uninsulated live electrical components at other than ground potential.

3.10 Containers — A cylinder or other vessels used to store the clean agent.

3.11 Container Discharge Valve — A valve directly connected to a container which when actuated releases the clean agent into the distribution piping.

3.12 Control Device — A device to control the sequence of events leading to the release of clean agent.

3.13 Concentration

3.13.1 Design Concentration — The concentration (including safety factor) of the clean agent necessary to extinguish a fire of a particular fuel.

3.13.2 Extinguishing Concentration — The concentration (without safety factor) of the agent necessary to extinguish a flame of a particular fuel at atmospheric pressure.

3.13.3 Hazardous Concentration — The concentration that exceeds the LOAEL (see 3.28) for the agent used.

3.13.4 Injected Concentration — The concentration of the agent necessary to develop under free efflux conditions the required design concentration.

3.13.5 Maximum Concentration — The concentration achieved from the actual clean agent quantity at the maximum ambient temperature.

3.13.6 Residual Oxygen Concentration — The resulting concentration of oxygen achieved within a protected area after the discharge of agent into the area.

3.14 Design Factor (DF) — A fraction of the agent minimum design quantity (MDQ) added thereto deemed appropriate due to a specific feature of the protection application or design of the suppression system.

3.15 Directional Valve — A device for controlling the passage of the clean agent from a supply manifold and directed to pre-selected area(s) of protection.

3.16 Discharge Inhibit Switch — A manually operated switch that prevents the automatic discharge of the clean agent.

3.17 Distribution System — All the pipe work and fittings downstream of any container discharge valve.

3.18 Engineered Systems — A system in which the supply of the clean agent stored centrally is discharged through a system of pipe and nozzles in which the size of each section of pipe and nozzle orifice has been calculated in accordance with relevant clauses of this standard. The design flow rates from nozzles may vary according to the design requirements of the hazard.

3.19 Fill Density — The mass of gaseous agent per unit volume of container (kg/m³).

3.20 Final Design Quantity (FDQ) — A quantity of agent determined from the agent minimum design quantity as adjusted to account for design factors and pressure adjustment.

3.21 Flooding Quantity — Mass or volume of clean agent required to achieve the design concentration within the protected volume within the specified discharge time.

3.22 Gross Volume — The volume enclosed by the building elements around the protected enclosure, less the volume of any permanent impermeable building elements within the enclosure.

3.23 Holding Time — Period of time during which a concentration of clean agent greater than the fire

extinguishing concentration surrounds the hazard.

3.24 Inert Gas Agent — A clean agent that contains as primary components one or more of the gases IG01, IG55, IG100 or IG541.

3.25 Inerting — The prevention of reignition of a flammable or explosive atmosphere by establishing a suitable concentration of the clean agent.

3.26 Liquefied Gas — A gas or gas mixture (normally a halocarbon) which is liquid at the container pressurization level at room temperature (20°C).

3.27 Lock-Off Valve — A mechanically operated device which prevents a clean agent from being discharged through distribution pipe work to the protected area.

3.28 Lowest Observed Adverse Effect Level (LOAEL) — The lowest concentration of clean agent at which an adverse toxicological or physiological effect has been observed.

3.29 Manual — Requires a human intervention to accomplish a function or task.

3.30 Maximum Working Pressure — Equilibrium pressure within a cylinder at the maximum working temperature. For liquefied gases, this is at maximum fill density and may include super-pressurization, if applicable.

3.31 Minimum Design Quantity (MDQ) — The quantity of agent required to achieve the calculated minimum design concentration.

3.32 Monitoring — The supervision of the operating integrity of an electrical, mechanical, pneumatic or hydraulic control feature of a system.

3.33 No Observed Adverse Effect Level (NOAEL) — The highest concentration of a clean agent at which no adverse toxicological or physiological effect has been observed.

3.34 Non-liquefied Gas — Gas or gas mixture which, under reserve pressure and allowable reserve temperature conditions, is always present in a gaseous form.

3.35 Normally Occupied Area — An area where, under normal circumstances, humans are present.

3.36 Normally Unoccupied Area — Area not occupied by people but may be occasionally entered for brief periods.

3.37 Nominal Size — A numerical designation of size which is common to all components in a piping system other than components designated by outside diameters or by thread size. It is a convenient round number for reference purposes and is only

loosely related to manufacturing dimensions.

3.38 Operating Device — Any component involved between actuation and release mechanisms.

3.39 Pre-engineered Systems — Those having pre-determined flow rates, nozzle pressures and quantities of clean agent. These systems have the specific pipe size, maximum and minimum pipe lengths, flexible hose specifications, number of fittings and number and types of nozzles prescribed by a testing laboratory.

3.40 Primary Release — Release of clean agent initiated by detection system or manual operation under normal operating conditions.

3.41 Release — The opening of the cylinder and directional valves leading to the physical discharge or emission of clean agent into the enclosure.

3.42 Safety Factor (SF) — A multiplier of the agent flame extinguishing or inerting concentration to determine the agent minimum design concentration.

3.43 Safety Interlock — A switch that monitors the occupation of the protected area and automatically inhibits the discharge of the clean agent when the area is occupied.

3.44 Sea Level Equivalent of Agent — The agent concentration (volume, percent) at sea level for which the partial pressure of agent matches the ambient partial pressure of agent at a given altitude.

3.45 Sea Level Equivalent of Oxygen — The oxygen concentration (volume, percent) at sea level for which the partial pressure of oxygen matches the ambient partial pressure of oxygen at a given altitude.

3.46 Secondary Release (Slave) — A release that is a consequence and dependent on the operation of the primary release, for example, pneumatic connection.

3.47 Super-pressurization — The addition of a gas to the clean agent container, where necessary, to achieve the required pressure for proper system operation.

3.48 Total Flooding — The act and manner of discharging an agent for the purpose of achieving a specified minimum agent concentration throughout a hazard volume.

3.49 Total Flooding Systems — A fire fighting system that is arranged to discharge clean agent into an enclosed space to achieve the appropriate design concentration.

4 GENERAL INFORMATION AND REQUIREMENTS

4.1 General

4.1.1 Extinguishing gases are three-dimensional agents that are used effectively to suppress fire through physical or chemical action. Separate properties of specific gases are provided in other parts of this standard.

4.1.2 Gaseous total flooding systems may be used to suppress fires of Classes A and B type as defined in 3.6 and 3.7. However, for suppressing fires where flammable gases may be present, the possibility of explosion, during and after system discharge should be considered.

4.1.3 Clean agent gas extinguishing systems are useful within the limits of this standard in extinguishing fires in specific hazards or equipment and in occupancies where an electrically non-conductive medium is essential or desirable, or where clean-up of other media poses a problem.

4.1.4 Where clean agent gas extinguishing systems are used, a fixed enclosure shall be provided about the hazard that is adequate to enable the specific concentration to be achieved and maintained for the specified period of time.

4.1.5 The effects of agent decomposition on fire protection effectiveness shall be considered when using clean agents in hazards with high temperatures (for example, furnaces and ovens, etc).

4.1.6 The design, installation, service and maintenance of the gas extinguishing systems shall be performed by those competent in the respective field in accordance with IS 15496 : 2004.

4.1.7 The installer of the clean agent system shall be certified by a reputed national/international agency/laboratory and such certification shall be valid at the time of installation.

4.2 Suitability and Application

4.2.1 Total Flooding Systems

Gaseous fire extinguishing systems are used primarily to protect hazards that are in enclosures or equipment that, in itself, includes an enclosure to contain the agent for establishment of required concentration and maintenance thereof for the required period. Some typical hazards that may be suitable include, but or not limited to, the following :

- a) Within enclosures, such as rooms, vaults, enclosed machines, containers, storage tanks and bins;

- b) For enclosed electrical hazards, such as transformers, control cubicles, switch boards, circuit breakers, and rotating equipment;
- c) For enclosed flammable liquid/gas storage and processing areas;
- d) For engines using flammable fuels;
- e) For electronic hazards, such as computers, data processing equipment, control room, telecommunication facilities;
- f) Sub-floors and other concealed spaces; and
- g) Other high value assets.

4.2.2 Some of the gaseous fire extinguishing systems may also be used for explosion prevention and suppression where flammable materials may collect in confined area.

4.3 Limitations

4.3.1 Gaseous fire extinguishing systems shall not be used on fires involving the following materials unless they are pre-evaluated for the purpose:

- a) Certain chemicals or mixture of chemicals, such as cellulose nitrate, gun powder, which are capable of rapid oxidation in the absence of air;
- b) Reactive metals, such as lithium, sodium, potassium, magnesium, titanium, zirconium, and plutonium;
- c) Metal hydrides or metal amides, some of which may react violently with some gaseous agents;
- d) Chemicals capable of undergoing auto-thermal decomposition, such as certain organic peroxides and hydrazine or;
- e) Mixtures containing oxidizing materials, such as sodium chlorate or sodium nitrate; and
- f) Environments where significant surface areas exist at temperatures greater than the breakdown temperature of the extinguishing agent and are heated by

means other than the fire.

4.3.2 Electrostatic charging of non-grounded conductors may occur during the discharge of gaseous fire extinguishing systems. These conductors may discharge to other objects causing an electric arc of sufficient charge to initiate explosion in potentially explosive atmospheres.

4.4 Other Information

4.4.1 All devices in respect of the gaseous fire extinguishing systems shall be designed for the service they will encounter and shall not be readily rendered inoperative or susceptible to accidental operation. Normally, the system components shall be designed to function properly from -21° to 55°C or marked to indicate temperature limitations in accordance with the specifications.

4.4.2 Gaseous fire extinguishing systems may be employed to protect more than one enclosure, if necessary, by means of directional valves. Where there are two or more enclosures simultaneously involved in a fire by reason of their proximity, such enclosures shall be protected by individual systems designed to allow simultaneous operation, or a single system sized and arranged to discharge on all potentially involved hazards simultaneously.

4.4.3 Systems employing simultaneous discharge of different agents to protect the same enclosure shall not be permitted.

4.5 Applicability of Clean Agents

4.5.1 The fire extinguishing clean agents addressed in the standard are electrically non-conducting and leave no residue upon evaporation.

4.5.2 Tables I and IA show the details of clean agents that are covered in this standard. While requirements that are common to all these agents are prescribed in this standard, individual requirements for each agent are covered under separate standards.

Table I Halocarbon Agents

(Clause 4.5.2)

SI No.	Clean Agent Formulae	Chemical Name	Commercial Name
(1)	(2)	(3)	(4)
i)	CHCl ₂ CF ₃ CHClF ₂ CHClFCF ₃ (Detoxifier)	Dichlorotrifluoroethane (HCFC-123, 4.75 percent) Chlorodifluoromethane (HCFC-22, 82 percent) Chlorotetrafluoroethane (HCFC-124, 9.5 percent) Isopropenyl-1-methylcyclohexane (3.75 percent)	HCFC Blend A
ii)	CF ₃ CHFCF ₃	Heptafluoropropane	HFC-227ea

Table 1A Inert Gas Agents

(Clause 4.5.2)

Sl No.	Clean Agent Formulae	Chemical Name	Commercial Name
(1)	(2)	(3)	(4)
i)	Ar	Argon (100 percent)	IG 01
ii)	N ₂	Nitrogen (100 percent)	IG 100
iii)	N ₂	Nitrogen (50 percent)	IG 55
	Ar	Argon (50 percent)	
iv)	N ₂	Nitrogen (52 percent)	IG 541
	Ar	Argon (40 percent)	
	CO ₂	Carbon dioxide (8 percent)	

4.5.3 As such, both these standards, that is, for general and individual requirements should be read together before designing a system. Where requirements in both the standards differ, standard covering individual requirements shall take precedence.

5 REQUIREMENTS REGARDING SUBMISSION OF PLANS

Plans shall contain sufficient details to enable an evaluation of the protected enclosure(s) or local protection(s) *vis-a-vis* the effectiveness of the system. Details shall include the property involved in the hazard(s), location(s), the enclosure limits and isolation of the hazards and the exposure of the hazards.

5.1 Plans for submission to the authorities shall be drawn up in accordance with the following requirements:

- Plans for integrity of fittings shall be clear, contain all required details including scale and point of compass and shall be clearly dated;
- Name of the enterprise, location and detailed postal address;
- Location and construction of the protected enclosures, walls and partitions;
- Cross and longitudinal sectional elevations of the protection enclosures showing the full height, schematic diagram, ceilings, false floors, etc;
- Type of clean agent proposed to be used;
- Concentration summary, that is, design, extinguishing, injected and inerting, etc;
- Type of the hazards proposed to be protected including descriptions of the occupancies, surroundings, wall/ceiling openings, etc;
- Location of the gas containers and

details of the contents, such as volume, pressure, nominal capacity in agent mass at standard conditions of temperatures and pressures;

- Descriptions of pipes and fittings indicating also their specifications, pressure ratings, etc;
- Descriptions of nozzles employed indicating their size, orifice area, type, angle, etc, and their locations;
- Electrical cabling and terminations;
- Descriptions of detectors employed indicating their locations, mounting, etc;
- Bill of material and equipment schedule for each component proposed for the system. Suppliers/manufacturers names, details of approvals, quantity, etc;
- Isometric drawings showing the agent distribution system indicating the lengths and diameters of each pipe segment, nodal reference, fittings including unions, reducers, orifices, strainers, nozzles, flow rates in all segments, equivalent orifice areas, etc;
- Plan view of the enclosures showing the entire agent piping system along with ceiling, floors, false floors, walls, partitions, pipe supports, agent containers, cabling, panels, detectors, etc;
- Details showing the pipe supports, agent container securement, etc;
- Location of ducts and similar devices, dampers, air handling systems, venting arrangements and their details with supporting calculations, etc;
- Schematic display of the operation of the system giving chronological sequence of operations prior to the discharge of the agent into the protected enclosures;
- Schematic diagrams showing the location

and layout of all the power and indicating equipment connections, control panels, annunciate panels, etc;

- w) Tables showing the calculations for enclosure volumes, agent quantity, methods used to determine number and location of audible and visual indicating equipment, number and location of detectors, etc; and
- y) Other features like interconnection with other type of fire protection systems, etc, with the proposed system.

5.2 The details of the system shall include information and calculations on the amount of agent; container storage pressure; internal volume of the containers; the location, type and flow rate of each nozzle including equivalent orifice area; the location, size and equivalent lengths of pipe, fittings, siphon tube, valve, discharge head and flexible connector hose; and the location and size of the storage facility. Pipe size reductions and orientation of tees shall be clearly indicated. Details shall be available on location and function of the detection devices, operating devices, auxiliary equipment and electrical circuitry. All the apparatus, equipment used in the system shall be easily identifiable.

5.3 An as-built drawing shall be submitted upon completion of the installation for approval. Instruction and maintenance manuals that include a full sequence of operations and a full set of drawings and calculations shall be available on site.

5.4 Flow Calculations

System flow calculations along with the working drawings shall be submitted to the authorities in advance for approval. The hydraulic calculations shall be performed using calculation method approved by the authorities.

6 SAFETY REQUIREMENTS

6.1 Safety Precautions (for Personnel)

The discharge of some of the gas agents in fire extinguishing concentrations creates serious hazards for personnel in both the protected area and the areas to which the gas may migrate and also to properties in the vicinity of agent discharge. These hazards may include reduced visibility, suffocation and toxicity, during and after the discharge period. The relevant information on the above is available in Annex B.

The toxicity information on the gaseous fire agents is given in Table 2. More details are specified in other relevant standard. Where hazardous concentrations of agent may exist, lock-off valves shall be fitted to the system.

In areas, where there is a likelihood of significant difference between gross and net volumes of the enclosure, utmost care shall be exercised in proper system design to ensure that maximum concentrations are not exceeded.

6.1.1 Safety Precautions (for Protected Areas)

- a) *Normally occupied area* — The minimum safety precautions taken shall be in accordance with Table 2A and provisions therein, and
- b) *Normally unoccupied areas* — The maximum concentration shall not exceed the LOAEL for the agent used unless a lock-off valve is fitted.

Warning — Any change to the enclosure volume, or addition or removal of contents that was not covered in the original design will affect the concentration of agent. In such instances the system shall be re-calculated to ensure that the required design concentration is achieved and that the NOAEL or the LOAEL are not exceeded.

6.1.2 For unoccupiable areas, the maximum concentration may exceed the LOAEL for the extinguishant used, without the need for a lock-off valve to be fitted.

6.1.3 Protection of Occupants

In any use of the gaseous system, where there is a possibility that people may enter or have difficulty seeking egress from the protected enclosure, suitable safeguards shall be provided. Such safety aspects as personal training, warning signs, pre-discharge alarms and safety interlocks shall be provided. Means of proper ventilation after fire should be readily available.

6.2 Safety Precautions (Total Flooding Systems)

6.2.1 In areas protected by total flooding systems, that are capable of being occupied, the provision of the following safety aspects shall apply:

- a) *Mandatory requirements:*
 - 1) A time delay shall be provided for evacuation prior to agent discharge. The agent discharge delay time shall be based on an engineering assessment of egress time for occupants in the area protected,
 - 2) Safety interlocks and lock-off valves shall be provided wherever required as per Table 2.

Table 2 Toxicity Information on Clean Agent Suppression Systems
(Clauses 6.1 and 6.2.1)

Sl No.	Clean Agent	Chemical Formula	NOAEL LOAEL LC50 or ALC (Percentage by Volume)		
			(4)	(5)	(6)
(1)	(2)	(3)			
i)	HCFC Blend A	CHCl ₂ CF ₃ (4.75 percent) CHClF ₂ (82 percent) CHClFCF ₃ (9.5 percent) Detoxifier (3.75 percent)	10	>10	64
ii)	HFC-227ea	CF ₃ CHFCF ₃	9	10.5	>80
iii)	IG-541	Nitrogen (52 percent) Argon (40 percent) Carbon dioxide (8 percent)	43	52	Not applicable
iv)	IG-55	Nitrogen (50 percent) Argon (50 percent)	43	52	Not applicable
v)	IG-100	Nitrogen (100 percent)	43	52	Not applicable
vi)	IG-01	Argon (100 percent)	43	52	Not applicable

Table 2A Minimum Safety Precautions
(Clauses 6.1.1 and 6.2.1)

Sl No.	Injected Agent Levels	Requirements			
		Inhibit Switch and Time Delay	Egress in 30 s	Safety Interlock	Lock-off Valve
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to NOAEL	Required	Not required	Not required	Not required
ii)	Above NOAEL and up to LOAEL	Required	Required	Required	Not required
iii)	Above LOAEL	Required	Not Applicable ¹⁾	Required	Required

NOTE — The purpose of the table is to avoid unnecessary exposure of occupants to the agent discharged. Factors such as the time for egress and the risk to the occupants by the fire must be considered when determining the system discharge time delay.

¹⁾Concentration levels above LOAEL are not permitted in occupied areas and question of egress does not arise.

- 3) Exit routes which shall be kept clear at all times and the provision of emergency lighting and adequate direction signs to minimize travel distances,
- 4) Outward swinging self-closing doors which can be opened from inside including when locked from the outside,
- 5) Continuous visual and audible alarms at entrances and designated exits until the protected area has been made safe,
- 6) Warning and instruction signs shall be arranged as per clause,
- 7) Pre-discharge alarms within such areas that are distinctive from all other alarm signals and that will operate immediately upon detection of fire,

- 8) Means of prompt ventilation of such areas after any discharge of agent. Forced draft ventilation will often be necessary. Care shall be taken to completely dissipate hazardous atmospheres and not just move them to other locations, as agents are generally heavier than air, and
- 9) Instructions and drills of all personnel within or in the vicinity of protected areas, including maintenance and construction personnel who may be brought into the area, to ensure their correct actions when the system operates.

b) *Recommendatory requirements:*

- 1) Adding an odour to the agent so that the hazardous atmospheres are recognizable,

- 2) Self-contained breathing apparatus and personnel trained for its use, and
- 3) Means to detect a hazardous atmosphere in or around the protected area.

6.2.2 Electrostatic Discharge

To avoid a situation as stated in 4.3.2, the components of the inerting system, such as pipe work, etc, shall be bonded and earthed as per National Electrical Code (SP 30 : 1985).

6.3 Miscellaneous Hazards

Certain other types of hazards associated with the usage of gaseous systems are as under:

- a) *Noise* — Discharge of a gaseous system can cause a noise loud enough to be startling, but not enough to cause traumatic injury;
- b) *Turbulence* — The turbulence caused by the high velocity discharge from nozzles may be sufficient to dislodge substantial objects directly in its path, such as ceiling tiles and light fittings. Therefore, tiles and light fittings should be properly anchored. System discharge may also cause enough general turbulence in the enclosure to move unsecured paper and light objects;
- c) *Electrical clearance* — Where exposed electrical conductors are present, all system components shall be located no less than the minimum clearances from the energized parts. The clearances stipulated in National Electrical Code shall be maintained for safe operating conditions. Where the design basic insulation level is not available and where nominal voltage is used for the design criteria the highest minimum clearance listed for the purpose shall be used; and
- d) Other hazards, if any, appropriate to the selected gaseous agent as specified in the other clauses of this standard shall be given due attention.

7 REQUIREMENTS FOR THE PROTECTED ENCLOSURES

7.1 Unclosable Openings

- a) The protected enclosure shall have sufficient structural strength and integrity to contain the agent discharge;
- b) The area of the unclosable openings such as ventilator openings within the enclosure shall be kept to as least as possible to avoid ingress of the agent through the leakages to the adjoining areas. Where confinement of the agent within the enclosure is not

practicable, protection shall be extended to include the adjacent connected hazards or work areas;

- c) Particular attention should be given to openings around cable, duct and pipelines (similar utility services) penetrating through the wall(s) and floor(s);
- d) In case of unavoidable openings, such openings should be restricted to as minimum as possible;
- e) In such cases, quantity of agent need to be suitably increased in consultation with the authorities concerned for maintaining the desired concentration within the enclosure;
- f) In case of item (c) above, the openings should be effectively sealed or preferably fire studded; and
- g) Injecting more quantity of agent in most of the cases, will only increase the rate of loss of agent through such openings. Hence, openings in the wall(s) and floor(s) shall be kept only to optimum requirements with increase in quantity of agent as discussed in item (d) above.

7.2 Air Handling System and Similar Services

- a) Humidification and air handling systems catering to the protected areas shall be capable of automatic shutdown prior to the agent discharge. Also dampers shall be available inside the systems to stop flow of agent through ducts and similar means and these shall close automatically prior to agent discharge;
- b) Where it is necessary for air handling systems to be kept operating to provide cooling arrangement for essential equipment, quantity of the agent shall need to be suitably increased to include the volumes of both air and the ventilation system in addition to the volume of protected enclosure in consultation with the authorities concerned for maintaining the desired concentration within the enclosure;
- c) The operations within the enclosure that are likely to disperse the discharge of the agent, such as pumps, spray guns, heaters, etc, shall not be left running during the discharge of the agent and suitable provisions shall be available to shut them down prior to agent discharge; and
- d) In case of extinguishment of deep-seated fires such as those involving solids. Unclosable openings shall be provided

only in the ceiling level and such openings near the walls and partitions shall be avoided.

8 COMPONENTS OF GASEOUS FLOODING SYSTEMS

8.1 Agent Supply and Container Arrangement

8.1.1 Agent Supply

- a) *Quality Requirement* — The clean agent shall comply with quality and purity standards appropriate to the agent selected for extinguishment. Each batch of agent manufactured shall be tested and certified to applicable specification. Agent blends shall remain homogeneous in storage and use within the approved temperature range and environmental conditions at the place of installation;
- b) *Quantity Requirements (Main)* — The amount of agent in the system shall be at least sufficient for the largest single hazard or group of hazards to be protected simultaneously;
- c) *Quantity Requirements (Reserve)* — Same quantity equivalent to the largest single hazard or group of hazards to be protected simultaneously shall be available as reserve. However, if the replenishing of agent supply takes more than 7 days at the site of installation, authority concerned may insist on more quantity to be kept available as reserve; and
- d) *Uninterrupted Protection* — Where uninterrupted protection is required, both the main and reserve supply shall be permanently connected to the distribution piping and arranged for easy change-over.

8.1.2 Agent Storage

- a) Agent shall be stored in containers designed to hold that specific agent at ambient temperatures,
- b) Agent containers shall be charged to a fill density or super-pressurization level with range specified by the manufacturers,
- c) Agent storage temperatures shall not exceed 55°C or be less than -21°C. External heating or cooling shall be employed to keep the temperature of the agent storage container within the above limits if situation warrants so,
- d) The agent containers used in the flooding systems shall be designed to meet the requirements of the Department of

Explosives, Nagpur,

- e) Each agent container shall have a permanent nameplate or other permanent marking that indicate the details as per Table 4.
- f) A reliable means shall be provided to determine the pressure in refillable super-pressurized containers, and
- g) The agent containers connected to a common manifold shall conform as per the provisions in Table 5.

Table 4 Marking on Storage Container

[Clause 8.1.2(e)]

SI No.	Clean Agent	Marking on Container
(1)	(2)	(3)
i)	Halocarbon clean	Name of the agent Tare and agents gross weights Super-pressurization level of the container
ii)	Inert gas clean agent	Name of the agent Pressurization level of the container Nominal agent volume

Table 5 Arrangement of Containers with Common Manifold

[Clause 8.1.2(g)]

SI No.	Clean Agent	Containers with Common Manifold
(1)	(2)	(3)
i)	Halocarbon clean agents	Agents in a multiple container system — all containers supplying the same manifold outlet for distribution of the same agent shall be interchangeable, of same nominal size and capacity, filled with same nominal mass of agent and pressurized to the same nominal working pressure
ii)	Inert gas clean agents	Agents shall be permitted to utilize multiple storage container sizes connected to the common manifold provided the containers are all pressurized to the same nominal working pressure

8.1.3 Storage Container Arrangement

The arrangement of storage containers and accessories shall be as follows:

- a) Containers and accessories shall be located and arranged so that inspection testing,

recharging and other maintenance is facilitated, and interruption to protection is kept to a minimum;

- b) Containers should be located outside and as near as practical to the enclosure protected. Containers protecting a single risk can be located within the enclosure they serve, only if sited so as to minimize the risk of exposure to fire and explosion;
- c) Containers shall be located so as not to be subject to severe weather conditions or to mechanical, chemical or other damage. Where excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided;
- d) Containers shall be adequately mounted to allow free passage of air around the base and suitably supported to provide for convenient individual servicing or content weighing. There shall be enough space for a full on-site inspection of the base of the container;
- e) In manifold systems, non-return valves or other automatic means shall be provided to prevent a loss of agent and to ensure personnel safety if the system is operated when any containers are removed for maintenance;
- f) Containers brackets or devices integral with the container for attachment to structures shall be designed to cater for the maximum expected mass, vibration effects and shock loading, appropriate to the installation;
- g) Reserve containers, where provided, shall be permanently sited or arranged for easy changeover; and
- h) Storage containers are located in areas where their leakage could lead to a hazardous concentration, consideration shall be given to the installation of gas detectors or other means to provide warning on the onset of hazardous conditions.

8.2 Agent Distribution Arrangements

8.2.1 General

- a) Pipe network, fitting shall be of non-combustible construction having physical and chemical properties such that their integrity under stress can be predicted with reliability;
- b) In severely corrosive atmospheres, special

corrosion resistant materials shall be required for pipes, fittings or support brackets and steelwork;

- c) Before final assembly, pipes and fittings shall be inspected visually to ensure they are free of burrs, swelter and rust and that no foreign matter is inside and the full bore is clear. After assembly, the system shall be thoroughly blown through with dry air or compressed gas. The pipe work shall be free of particulate matter and oil residue before the installation of nozzles and discharge devices;
- d) A dirt trap consisting of a 'tee' with a capped nipple at least 50 mm long should be installed at the end of each pipe run. Drain traps should also be necessary if there is a possibility of a build-up of water;
- e) In systems where valve arrangements introduce sections of closed piping, such sections shall be equipped with the following:
 - 1) Indication of agent trapped in piping;
 - 2) Means for safe manual venting; and
 - 3) Automatic relief of excess pressure, where required.
- f) Pressure relief devices, which can include the selector valve, shall be fitted so that the discharge, in the event of operation, will not endanger the personnel; and
- g) In systems using pressure-operated container valves, automatic means shall be provided to vent any container leakage that could build up pressure in the pilot system and cause unwanted opening of the container valve. The means provided for pressure venting shall not prevent operation of the container valve.

8.2.2 Piping Network

8.2.2.1 The piping used in the installation shall conform to the following requirements:

- a) Cast iron or non-metallic pipes shall not be used anywhere;
- b) Where used, flexible pipes, tubing, or hoses including connections shall be of approved materials with adequate temperature and pressure ratings; and
- c) The thickness of the pipes shall be in accordance with the provisions laid down in IS 6631. The internal pressure used for this calculation shall not be less than the greater of either of the following values:

- 1) The normal charging pressure in the agent container at 21°C.
- 2) 80 percent of the maximum pressure in the agent container at the maximum storage temperature of not less than 55°C using the maximum allowable fill density specified by the manufacturer, if applicable.
- d) Pipe joints shall be either threaded, welded or flanged type only and other types of jointing shall not be allowed.

In no case shall the value used, for the minimum piping design pressure, be less than that specified in Tables 6 and 7 for the conditions shown.

For halocarbon agents Table 6 shall be used and for inert gas agents Table 7 shall be used.

Where different fill densities, pressurization levels or higher storage temperatures other than the

values shown in the tables are used with prior acceptance of the authorities, the minimum design pressure for the piping shall be adjusted to the maximum pressure in the agent container at maximum temperature, using the basic design criteria specified in items c(1) and c(2) above.

8.2.3 Pipe Fittings

- a) The sizes and dimensions of pipe fittings shall be in accordance with IS 1239 (Part 2). Fittings shall be capable to withstand minimum rated working pressure equal to or greater than the minimum working pressure specified in 8.2.2.1 (c) for the clean agent being used. For systems that use a pressure reducing device in the distribution piping, the fittings downstream the device shall have a minimum rated working pressure equal to or greater than the maximum anticipated pressure in the downstream piping;

Table 6 Minimum Design Working Pressure for Halocarbon Clean Agent System Piping
(Clause 8.2.2.1)

Sl No.	Clean Agent	Agent Container Maximum Fill Density kg/m ³	Agent Container Charging Pressure at 21°C kPa	Agent Container Charging Pressure at 55°C kPa	Minimum Piping Design Pressure at 21°C kPa
(1)	(2)	(3)	(4)	(5)	(6)
i)	HFC-227ea	992 1 152 1 120	1 034 ¹⁾ 2 482 ¹⁾ 4 137 ¹⁾	1 703 3 585 4 950	1 365 2 868 3 958
ii)	HCFC Blend A	900 900	4 137 ¹⁾ 2 482 ¹⁾	5 860 3 723	4 689 2 979

¹⁾Super-pressurized with nitrogen.

Table 7 Minimum Design Working Pressure for Inert Gas Clean Agent System Piping
(Clause 8.2.2.1)

Sl No.	Clean Agent	Agent Container Charging Pressure at 21°C kPa	Agent Container Charging Pressure at 55°C kPa	Minimum Design Pressure at 21°C	
				Piping Upstream of Pressure Reducer kPa	Piping Downstream of Pressure Reducer kPa
(1)	(2)	(3)	(4)	(5)	(6)
i)	IG-01	16 341 20 424	18 271 22 778	16 341 14 997	6 723 6 728
ii)	IG-541	14 997 19 996	17 755 23 671	14 997 19 996	6 895 6 895
iii)	IG-55	15 521 20 424 30 636	17 065 22 753 34 130	15 318 20 424 30 635	6 550 6 550 6 550
iv)	IG-100	16 580 22 311	19 300 26 014	16 580 22 311	6 895 6 895

- b) Cast iron fittings shall not be used All threads used in joints and fittings shall comply with relevant Indian Standards;
- c) Welding of joints shall comply with relevant Indian Standards; and.
- d) Where copper, stainless steel, or other suitable tubing is jointed with compression type fittings, manufacturers pressure and temperature ratings of the fittings shall not be exceeded.

8.2.4 Pipe Installation and Supports

- a) In the installation of pipe work, care shall be taken to avoid possible restrictions due to foreign matter, faulty fabrication or improper installation. Pipe ends shall be reamed after cutting, where required;
- b) Where there is a possibility of explosions, the piping shall be attached to supports that are least likely to be displaced; and
- c) The maximum distance between supports shall take into account the total mass of pipe and the agent used. Distance between supports is indicated in Table 8.

Table 8 Maximum Pipe Work Distances

[Clause 8.2.4(c)]

Sl No.	Nominal Diameter of Pipe mm	Maximum Pipe Work Distance mm
(1)	(2)	(3)
i)	6	0.5
ii)	10	1
iii)	15	1.5
iv)	20	1.8
v)	25	2.1
vi)	32	2.4
vii)	40	2.7
viii)	50	3.4
ix)	65	3.5
x)	80	3.7
xi)	100	4.3
xii)	125	4.8
xiii)	150	5.2
xiv)	200	5.8

8.2.5 Discharge Nozzles

- a) Nozzles, including nozzles directly attached to containers, shall be of approved type and located with the geometry of the enclosure under consideration.
- b) The type, number and placement of

nozzles shall be such that:

- 1) The design concentration shall be achieved in all parts of the enclosure;
 - 2) The discharge shall not unduly splash flammable liquids or create dust clouds that might extend the fire, create an explosion or otherwise adversely affect the occupants;
 - 3) The velocity of discharge shall not adversely affect the enclosure or its contents;
 - 4) The discharge nozzles shall be provided with frangible discs or blow-out caps where clogging by foreign materials is possible. These devices shall provide an unobstructed opening upon system operation and shall be arranged so they will not injure personnel;
 - 5) Nozzle shall be suitable for the intended use and shall be approved for discharge characteristics. The discharge nozzle consists of the orifice and any associated horn, shield or baffle;
 - 6) Nozzles shall be of adequate strength for use with the expected working pressures, be able to resist nominal mechanical abuse, and be constructed to withstand expected temperatures without deformation; and
 - 7) Nozzle discharge orifice inserts shall be of corrosion-resistant material.
- c) In order to minimize the possibility of lifting or displacement of lightweight ceiling tiles, precautions shall be taken to securely anchor the tiles for a minimum distance of 1.5 m from each discharge nozzle.

9 DETECTION, ACTUATION, ALARM AND CONTROL SYSTEMS

9.1 General

9.1.1 Detection, actuation, alarm and control systems shall be installed, tested and maintained in accordance with IS 2189.

9.1.2 Automatic detection and automatic actuation shall be used.

9.2 Automatic Detection

9.2.1 Automatic detection shall be by any approved method or device capable of detecting and indicating heat, flame, smoke, combustible vapours or any abnormal condition in the hazard, such as process trouble, that is likely to produce fire.

9.2.2 Adequate and reliable primary and 24 h minimum standby sources of energy shall be used to provide for operation of the detection, signalling, control and actuation requirements of the system.

9.2.3 When a new agent system is being installed in a space that has an existing detection system, an analysis shall be made of the detection devices to assure that the detection system is in good operating condition and will respond promptly to a fire situation. This analysis shall be done to assist in limiting the decomposition products from a suppression event.

9.3 Operating Devices

9.3.1 Operating devices shall include agent releasing devices or valves, discharge controls and shutdown equipment necessary for successful performance of the system.

9.3.2 Operation shall be by approved mechanical, electrical or pneumatic means, adequate and reliable source of energy shall be used.

9.3.3 All devices shall be designed for the service they will encounter and shall not readily be rendered inoperative or susceptible to accidental operation. Devices normally shall be designed to function properly from -20° to 55°C or marked to indicate temperature limitations.

NOTE — Also care shall be taken to thoroughly evaluate and correct any factors that could result in unwanted discharge.

9.3.4 All devices shall be located, installed or suitably protected so that they are not subject to mechanical, chemical or other damage that would render them inoperative.

9.3.5 A mean of manual release of the system shall be provided. Manual release shall be accomplished by a mechanical manual release or by an electrical manual release when the control equipment monitors the battery voltage level of the standby battery supply and will provide a low battery signal. The release shall cause simultaneous operation of automatically operated valves controlling agent release and distribution.

9.3.6 The normal manual control(s) for actuation shall be located for easy accessibility at all times, including at the time of a fire. The manual control(s) shall be of distinct appearance and clearly recognizable for the purpose intended. Operation of any control shall cause the complete system to operate in its normal fashion.

9.3.7 Manual controls shall not require a pull of more than 18.1 kg (178 N) nor a movement of more than 355 mm to secure operation. At least one manual

control for activation shall be located not more than 1.2 m above the floor.

9.3.8 Where gas pressure from the system or pilot containers is used as a means for releasing the remaining containers, the supply and discharge rate shall be designed for releasing all of the remaining containers.

9.3.9 All devices for shutting down supplementary equipment shall be considered integral part of the system and shall function with the system operation.

9.3.10 All manual operating devices shall be identified as to the hazard they protect.

9.4 Control Equipment

9.4.1 Electric Control Equipment

The control equipment shall supervise the actuating devices and associated wiring and, as required, cause actuation. The control equipment shall be specifically listed for the number and type of actuating devices utilized and their compatibility shall have been approved.

9.4.2 Pneumatic Control Equipment

Where pneumatic control equipment is used, the lines shall be protected against crimping and mechanical damage. Where installations could be exposed to conditions that could lead to loss of integrity of the pneumatic lines, special precautions shall be taken to ensure that no loss of integrity will occur. The control equipment shall be specifically listed for the number and type of actuating devices utilized and their compatibility shall have been approved.

9.5 Operating Alarms and Indicators

9.5.1 Alarms or indicators or both shall be used to indicate the operation of the system, hazards to personnel, or failure of any supervised device. The type (audible, visual or olfactory), number, and location of the devices shall be such that their purpose is satisfactorily accomplished. The extent and type of alarms or indicator equipment or both shall be approved.

9.5.2 Audible and visual pre-discharge alarms shall be provided within the protected area to give positive warning of impending discharge. The operation of the warning devices shall be continued after agent discharge until positive action has been taken to acknowledge the alarm and proceed with appropriate action.

9.5.3 Abort switches generally are not recommended, however, where provided, the abort

switches shall be located within the protected area and shall be located near the means of egress from the area. An abort switch shall not be operated unless the cause for the condition is known and corrective action can be taken. The abort switch shall be of a type that requires constant manual pressure to cause abort. The abort switch shall not be of a type that would allow the system to be left in an aborted mode without someone present. In all cases the normal and manual emergency control shall override the abort function. Operation of the abort function shall result in both audible and distinct visual indication of system impairment. The abort switch shall be clearly recognizable for the purpose intended.

9.5.4 Alarms indicating failure of supervised devices or equipment shall give prompt and positive indication of any failure and shall be distinctive from alarms indicating operation or hazardous conditions.

9.5.5 Warning and instruction signs at entrances to and inside protected areas shall be provided.

9.5.6 Indication lamps shall be provided to indicate the status of the abort switch, that is, Green colour for 'Auto', Yellow colour for the 'Manual' and Red colour for 'Discharge' modes.

9.6 Time Delays

9.6.1 For clean agent extinguishing systems, a pre-discharge alarm and time delay, sufficient to allow personnel evacuation prior to discharge, shall be provided. For hazard areas subject to fast growth fires, where the provision of a time delay would seriously increase the threat to life and property, a time delay shall be permitted to be eliminated.

9.6.2 Time delays shall be used only for personnel evacuation or to prepare the hazard area for discharge.

9.6.3 Time delays shall not be used as a means of confirming operation of a detection device before automatic actuation occurs.

10 COMMISSIONING AND ACCEPTANCE

The minimum requirements for the commissioning and acceptance of the gaseous extinguishing system shall be as follows.

10.1 General

The completed system shall be reviewed and tested by a competent person to meet the approval of the authority. Only equipment and devices designed to national standards shall be used in the systems.

To determine that the system has been properly installed and will function as specified, the tests specified in 10.2.2 to 10.2.9 shall be performed.

10.2 Review of Mechanical Components

10.2.1 The piping distribution system shall be inspected to determine that it is in compliance with the design and installation documents.

10.2.2 Nozzles and pipe size and, if appropriate, pressure-reducing devices, shall be in accordance with system drawings. The means for pipe size reduction and attitudes of tees shall be checked for conformance to the design.

10.2.3 Piping joints, discharge nozzles and piping supports shall be securely fastened to prevent unacceptable vertical or lateral movement during discharge. Discharge nozzles shall be installed in such a manner that piping cannot become detached during discharge.

10.2.4 During assembly, the piping distribution system shall be inspected internally to detect the possibility of any oil or particulate matter which could soil the hazard area or affect the agent distribution due to a reduction in the effective nozzle orifice area.

10.2.5 The discharge nozzles shall be oriented in such a manner that optimum agent dispersal can be effected.

10.2.6 If nozzle deflectors are installed, they shall be positioned to obtain the maximum benefit.

10.2.7 The discharge nozzles, piping and mounting brackets shall be installed in such a manner that they will not potentially cause injury to personnel. Agent shall not directly impinge on areas where personnel may be found in the normal work area, or on any loose objects or shelves, cabinet tops, or similar surfaces where loose objects could be present and become missiles.

10.2.8 All agent storage containers shall be properly located in accordance with 'approved for construction' set of system drawings.

10.2.9 All containers and mounting brackets shall be securely fastened in accordance with the manufacturer's requirements.

10.2.10 An adequate quantity of agent to produce the desired specified concentration shall be provided. The actual enclosure volumes shall be checked against those indicated on the system drawings to ensure the proper quantity of agent. Fan rundown and damper closure time shall be taken into consideration.

10.2.11 Unless the total piping contains not more than one change in direction fitting between the storage container and the discharge nozzle, and unless all piping has been physically checked for tightness, the following tests shall be carried out:

- a) All open ended piping shall be pneumatically tested in a closed circuit for a period of 10 min at 3 bar. At the end of 10 min, the pressure drop shall not exceed 20 percent of the test pressure, and
- b) All closed-section pipe work shall be hydrostatically tested to a minimum of 1.5 times the maximum working pressure for 2 min during which there shall be no leakage. On completion of the test, the pipe work shall be purged to remove moisture.

It is recommended that hydrostatic testing be carried out at the manufacturer's works where practicable.

WARNING — Pneumatic pressure testing creates a potential risk of injury to personnel in the area, as a result of airborne projectiles if rupture of the piping system occurs. Prior to conducting the pneumatic pressure test, the protected area shall be evacuated and appropriate safeguards shall be provided for test personnel.

10.2.12 A test using nitrogen, or a suitable alternative, shall be performed on the piping network to verify that flow is continuous and that the piping and nozzles are unobstructed.

10.2.13 Where required, suitable venting facilities shall be provided for the release of excessive pressure build-up during discharge of the agent. Individual standards for gaseous agents provide details for the design of venting facilities.

10.3 Review of Electrical Components

10.3.1 All wiring systems shall be properly installed in compliance with the appropriate National Standard and the system drawings. a.c. and d.c. wiring shall not be combined in a common conduit unless properly shielded and grounded.

10.3.2 All field circuitry shall be tested for ground fault and short circuit condition. When testing field circuitry, all electronic components (such as smoke and flame detectors or special electronic equipment for other detectors, or their mounting bases) shall be removed and jumpers properly installed to prevent the possibility of damage within these devices. Replace components after testing the circuits.

10.3.3 Adequate and reliable primary standby sources of energy which comply with 9.2.2 shall be used to provide for operation of the detection,

signalling, control and actuation requirements of the system.

10.3.4 All auxiliary functions (such as alarm sounding or displaying devices, remote annunciators, air handling shutdown, power shutdown, etc) shall be checked for proper operation in accordance with system requirements and design specifications.

Alarm devices shall be installed so that they are audible and visible under normal operating and environmental conditions.

Where possible, all air handling and power cut-off controls should be of the type that once interrupted require manual restart to restore power.

10.3.5 Check that for systems using alarm silencing, this function does not affect other auxiliary functions, such as air handling or power cut-off where they are required in the design specification.

10.3.6 Check the detection devices to ensure that the types and locations are as specified in the system drawings and are in accordance with the manufacturer's requirements.

10.3.7 Check that manual release devices are properly installed, and are readily accessible, accurately identified and properly protected to prevent damage.

10.3.8 Check that manual release devices used to release agents require two separate and distinct actions for operation. They shall be properly identified. Particular care shall be taken where manual release devices for more than one system are in close proximity and could be confused or the wrong system actuated. Manual release devices in this instance shall be clearly identified as to which hazard enclosure they protect.

10.3.9 Check that for systems with a main/reserve capability, the main/reserve switch is properly installed, readily accessible and clearly identified.

10.3.10 Check that for systems using inhibit switches requiring constant manual force, these are properly installed, readily accessible within the hazard area and clearly identified.

10.3.11 Check that the control panel is properly installed and readily accessible.

10.4 Preliminary Functional Tests

10.4.1 Where a system is connected to a remote central alarm station, notify the station that the fire system test is to be conducted and that an emergency response by the fire department or alarm station personnel is not required. Notify all concerned personnel at the end-user's facility that a test is to

be conducted and instruct them as to the sequence of operation.

10.4.2 Disable or remove each agent storage container release mechanism and selector valve, where fitted, so that activation of the release circuit will not release agent. Reconnect the release circuit with a functional device in lieu of each agent storage container release mechanism.

For electrically actuated release mechanisms, these devices may include suitable lamps, flash bulbs or circuit breakers. Pneumatically actuated release mechanisms may include pressure gauges. Refer to the manufacturer's recommendations in all cases.

10.4.3 Check each resetable detector for proper response.

10.4.4 Check that polarity has been observed on all polarized alarm devices and auxiliary relays.

10.4.5 Check that all required end-or-line devices have been installed.

10.4.6 Check all supervised circuits for correct fault response.

10.5 System Functional Operational Test

10.5.1 Operate the detection initiating circuit(s). All alarm functions shall occur according to the design specification.

10.5.2 Operate the necessary circuit to initiate a second alarm circuit if present. Verify that all second alarm functions occur according to design specifications.

10.5.3 Operate the manual release device. Verify that manual release functions occur according to design specifications.

10.5.4 Where appropriate, operate the inhibit switch. Verify that functions occur according to the design specifications. Confirm that visual and audible supervisory signals are received at the control panel.

10.5.5 Check the function of all resettable valves and activators, unless testing the valve will release agent. 'One-shot' valves, such as those incorporating frangible discs, should not be tested.

10.6 Remote Monitoring Operations (If Applicable)

10.6.1 Disconnect the primary power supply, then operate one of each type of input device while on standby power. Verify that an alarm signal is received at the remote panel after the device is operated. Reconnect the primary power supply.

10.6.2 Operate each type of alarm condition and verify receipt of fault condition at the remote station.

10.7 Control Panel Primary Power Source

10.7.1 Verify that the control panel is connected to a dedicated unswitched circuit and is labelled properly. This panel shall be readily accessible but access shall be restricted to authorized personnel only.

10.7.2 Test a primary power failure in accordance with the manufacturer's specification, with the system fully operated on standby power.

10.8 Review of Enclosure Integrity

It is preferable to subject all total flooding systems to an Enclosure Integrity Test in order to detect and seal the significant leakage paths that could result in failure of an enclosure to withhold design concentration for a specified period (*see* 7.1 and 10.10).

10.9 Completion of Functional Tests

When all functional tests are complete (*see* 10.6 to 10.9), reconnect each storage container so that activation of the release circuit will release the agent. Return the system to its fully operational design condition. Notify the central alarm station and all concerned personnel at the end-user's facility that the fire system test is complete and that the system has been returned to full service condition by following the procedures specified in the manufacturers' specifications.

10.10 The complete installation shall be tested in one of the two methods narrated below:

- a) Full-scale discharge test, and
- b) Enclosure integrity test.

Where the authorities concerned insist on full-scale discharge test, the test shall be conducted in accordance with various provisions under Annex C and results of the test (that is concentration achieved, discharge time, holding time) shall conform to various provisions available in other clean agent standards with particular reference to the agent used. Otherwise, the enclosure where total flooding system is installed, shall be subject to 'enclosure integrity test' in accordance with various provisions under Annex D to demonstrate the retention time (of the required concentration with the enclosure) as specified in other standards with particular reference to the agent used.

10.11 Completion Certificate and Documentation

The installer shall provide to the user a completion

certificate, a complete set of instructions, calculations and drawings showing the system as-installed, and a statement that the system complies with all the appropriate requirements of this standard, and giving details of any departure from appropriate recommendations. The certificate shall give the design concentrations and, if carried out, reports of any additional test including the door fan test.

11 SYSTEM HYDRAULIC FLOW CALCULATIONS

11.1 General

System flow calculations shall be carried out at a nominal agent storage temperature of 21°C, shall have been validated by an accredited approval authority by appropriate tests as described in this standard, and shall be properly identified. The system design shall be within the manufacturer's specified limitations.

NOTES

- 1 Variations from the nominal 21°C storage temperature will affect flow conditions used in calculations.
- 2 Pre-engineered systems do not require a flow calculation when used within approved limitations.

11.2 Balanced and Unbalanced System

11.2.1 A balanced system shall be one in which:

- a) each actual or equivalent pipe length from the container to each nozzle are all within 10 percent of each other, and
- b) the discharge rate of each nozzle is equal.

11.2.2 Any system that does not meet the criteria mentioned in 11.2 shall be considered to be an unbalanced system.

11.3 Friction Losses

Allowance shall be made for the friction losses in pipes and in container valves, dip tubes, flexible connectors, selector valves, time delay devices and other equipment (for example, pressure-reducing devices) within the flow line.

NOTE — The flow of a liquefied gas will be a two phase phenomenon, the fluid consisting of a mixture of liquid and vapour, the proportions of which are dependent on pressure and temperature. The pressure drop is non-linear, with an increasing rate of pressure loss as the line pressure reduces by pipe friction.

11.4 Pressure Drop

The pressure drop shall be calculated using two phase flow equations for liquefied gases and single phase flow equations for non-liquefied gases.

NOTE — These equations use friction factors and constants dependent on pressure and density obtained empirically. As the equations cannot be solved directly, a computer programme is usually used to assist with the large number of iterative calculations in which pipe and nozzle sizes and if appropriate, size of pressure reducing devices, are selected within prescribed pressure losses.

11.5 Valves and Fitting

Valves and fittings shall be rated for resistance coefficient or equivalent length in terms of pipe, or tubing sizes with which they will be used. The equivalent length of the cylinder valves shall be listed and shall include siphon tube (where fitted), valve, discharge head and flexible connector.

11.6 Piping Length

The piping length and nozzle and fitting orientation shall be in accordance with the manufacturer's approved manual to ensure proper system performance.

11.7 Drawings

If the final installation varies from the prepared drawings and calculations new 'as- built' drawings and calculations shall be prepared.

11.8 Liquefied Gases (Specific Requirements)

11.8.1 Allowance shall be made for changes in elevation as specified in the relevant standard relating to the specific agent.

11.8.2 Minimum discharge rate for liquefied agents shall be sufficient to maintain the velocity required for turbulent flow to prevent separation.

NOTE — If turbulent flow is not maintained, separation of the liquid and gaseous phases will occur, which can lead to unpredictable flow characteristics.

11.8.3 For information on two-phase flow for liquefied halocarbon gases (*see* Annex E).

12 ENGINEERED AND PRE-ENGINEERED SYSTEM

12.1 General

All agents are suitable for use in both engineered central storage, system and pre-engineered (modular or packaged) systems, as described in 12.2 and 12.3.

12.2 Engineered

An engineered system uses large storage containers installed in central location. The containers are manifold together and a single pipe feeds the nozzle located inside the

hazard area. Predicting pipe pressure losses and designing nozzle orifice sizes required complex flow calculations for both agent and nitrogen phases (in case of halocarbon gases) and for agent (in case of line gases), which takes into account the minimum and maximum volumes or the enclosure.

12.3 Pre-engineered

A pre-engineered system involves a single container the maximum of two nozzles and a small piping network. This system can be multiplied to cover larger volume areas. The larger area is viewed as a number of smaller areas each protected by a single modular unit.

13 PHYSICAL PROPERTIES

Physical properties of inert gas and halocarbon agents are shown in the Tables 9 and 10.

14 TRAINING

14.1 All persons who may be expected to operate, maintain, test or inspect fire extinguishing systems shall be kept continuously and adequately trained in the functions they are expected to perform.

14.2 Personal working in an enclosure protected by or gaseous extinguishant shall be trained and kept fully conversant with the operation and use of the system, particularly regarding safety requirements.

Table 9 Physical Properties of Inert Gas Agents
(Clause 13)

Sl No.	Properties	Units	IG-01	IG-100	IG-541	IG-55
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Molecular weight	N/A	39.9	28.0	34.0	33.95
ii)	Boiling point at 760 mm Hg	°C	-189.85	-195.8	-196	-190.1
iii)	Freezing point	°C	-189.85	-210.0	-78.5	-199.7
iv)	Critical temperature	°C	-122.3	-146.9	N/A	-134.7
v)	Critical pressure	kPa	4 903	3 399	N/A	4 150
vi)	Specific heat, vapour at constant pressure (1 atm) and 25°C	Kj/kg°C	0.519	1.04	0.574	0.782
vii)	Heat of vaporization at boiling point	Kj/kg	163	199	220	181
viii)	Relative dielectric strength at 1 atm at 734 mm Hg, 25°C (N ₂ = 1.0)	N/A	1.01	1.0	1.03	1.01
ix)	Solubility of water in agent at 25°C	N/A	0.006 percent	0.001 3 percent	0.015 percent	0.006 percent

Table 10 Physical Properties of Clean Halocarbon Agents

(Clause 13)

SI No.	Properties	Units	HCFC Blend A	HFC 227ea
(1)	(2)	(3)	(4)	(5)
i)	Molecular weight	N/A	92.90	170.03
ii)	Boiling point at 760 mm Hg	°C	-38.3	-16.4
iii)	Freezing point	°C	<107.2	-131
iv)	Critical temperature	°C	124.4	-101.7
v)	Critical pressure	kPa	6 647	2 912
vi)	Critical volume	Cc/mole	162	274
vii)	Critical density	kg/m ³	577	621
viii)	Specific heat, liquid at 25°C	Kj/kg°C	1.256	1.184
ix)	Specific heat vapour at constant pressure (1 atm) and 25°C	Kj/kg °C	0.67	0.808
x)	Heat of vaporization at boiling point at 25°C	Kj/kg	225.6	132.6
xi)	Thermal conductivity of liquid at 25°C	W/m°C	0.090 0	0.069
xii)	Viscosity, liquid at 25°C	Centipoises	0.21	0.184
xiii)	Relative dielectric strength at 1 atm at 734 mm Hg, 25°C (N ₂ = 1.0)	N/A	1.32	2.00
xiv)	Solubility of water in agent at 21°C	Ppm	0.12 percent by weight	0.006 percent by weight

ANNEX A

(Clause 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	Title	IS No.	Title
1239 (Part 2): 1992	Mild steel tubes, tubulars and other wrought steel fittings: Part 2 Mild steel tubulars and other wrought steel pipe fittings (<i>fourth revision</i>)	6631:1972	Specification for steel pipes for hydraulic purposes
		SP 30: 1985	National Electrical Code
2189:1999	Selection, installation and maintenance of automatic fire detection and alarm system — Code of practice	15496:2004	Inspection and maintenance of gaseous fire extinguishing systems — Code of practice

ANNEX B

(Clause 6.1)

INFORMATION ON SAFETY TO PERSONNEL AND DECOMPOSITION PRODUCTS OF COMBUSTION

B-1 Any hazard to personnel created by the discharge of gaseous extinguishants shall be considered in the design of the system, in particular with reference to the hazards associated with particular extinguishants in the other standards of clean agents. Unnecessary exposure to all gaseous extinguishants shall be avoided.

B-2 The decomposition products generated by the clean agent breaking down in the presence of very high amounts of heat can be hazardous. All of the present halocarbon agents contain fluorine. In the presence of available hydrogen (from water vapour, or the combustion process itself), the main decomposition product is hydrogen fluoride (HF).

B-3 These decomposition products have a sharp, acrid odour, even in minute concentrations of only a few parts per million. This characteristic provides a built-in warning system for the agent, but at the same time creates a noxious, irritating atmosphere for those who must enter the hazard following a fire.

B-4 The amount of agent that can be expected to decompose in extinguishing a fire depends to a large extent on the size of the fire, the particular clean agent, the concentration of the agent, and the length of time the agent is in contact with the flame or heated surface. If there is a very rapid build-up of concentration to the critical value, then the fire will be extinguished quickly and the decomposition will be limited to the minimum possible with that agent. Should that agent's specific composition be such that it could generate large quantities of decomposition products, and the time to achieve the critical value is lengthy, then the quantity of decomposition products can be quite great. The actual concentration of the decomposition products then depends on the volume of the room in which the fire was burning and on the degree of mixing and ventilation.

B-5 Although the vapour from halocarbon gas has low toxicity, the decomposition products can be very hazardous. The most widely accepted theory is

that the vapour must decompose before the agent can inhibit the combustion reaction. Decomposition takes place on exposure to a flame or to a hot surface at a temperature above 480°C. In the presence of available hydrogen (from water vapour or the combustion process itself), the main decomposition product is hydrogen fluoride (HF).

B-6 The decomposition products of halocarbon agents have a characteristic sharp acrid odour, even in minute concentrations of only a few parts per million. This characteristic provides a built-in warning system for the extinguishant, but at the same time creates a noxious, irritating atmosphere for those who have to enter the enclosure following a fire. The actual concentration of the decomposition products depends on the volume of the enclosure in which fire is burning and the degree of mixing and ventilation.

B-7 Longer exposure of the vapour to temperatures in excess of 482°C would produce greater concentrations of these gases. The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the vapours to the elevated temperature if the concentration of breakdown products is to be minimized. In most cases, the area would be untenable for human occupancy due to the heat and breakdown products of the fire itself.

B-8 Clearly, longer exposure of the agent to high temperatures would produce greater concentrations of these gases. The type and sensitivity of detection, coupled with the rate of discharge, should be selected to minimize the exposure time of the agent to the elevated temperature if the concentration of the breakdown products is to be minimized.

B-9 Non-liquefied agents do not decompose measurably in extinguishing a fire. As such, toxic or corrosive decomposition products are not found. However, breakdown products of the fire like carbon monoxide itself can still be substantial and could make the area untenable for human occupancy.

ANNEX C

(Clause 10.10)

REQUIREMENTS FOR FULL-SCALE DISCHARGE TEST

C-1 SCOPE

This clause sets out a procedure to determine compliance of the gaseous total flooding system with the requirements for discharge time, concentration and holding time.

C-2 PRINCIPLE

The system is operated, discharge time is measured and concentration readings are taken at a specified height at nominated periods.

C-3 TEST MEDIUM

The test medium shall be the concerned halocarbon or inert gas.

C-4 APPARATUS

The following apparatus is required:

- a) A chart recorder type concentration meter calibrated in strict accordance with the manufacturer's instructions,
- b) A suitable time-measuring device, and
- c) Temperature-measuring equipment.

C-5 PROCEDURE

The procedure shall be as follows:

- a) Ensure that the preliminary checks, in accordance with respective standard pertaining to gaseous fire extinguishing system have been completed,
- b) Electrically isolate all flooding systems serving adjacent enclosures,
- c) 1) Concentration measurements should be made at a minimum of three points, one at the highest hazard level,
2) Locate sampling points in the enclosure at the specified heights (*see 10*). Do not locate sampling points nearer than 200 mm to ceiling unless the combustibles being protected extend within that area, in which case special design considerations may be necessary,
3) If more than one space or compartment is being simultaneously protected, locate a sampling point in each space in accordance with the above criteria. Additional sampling points may be

required by the appropriate authority, and

- 4) Where the geometry of the enclosure does not lend itself to sampling in the above manner, take a minimum of three samples at locations agreed upon by the appropriate authority.
- d) Set the continuous chart recorder type concentration meter for the agent concerned and check that the meter is calibrated in accordance with the manufacturer's instructions so that it will record concentration levels at each sampling point for 10 min from commencement of discharge,
- e) Record temperature in enclosure,
- f) Ensure that plant which is capable of affecting system performance, for example, air-handling plant is in its normal operating mode,
- g) Activate the system and record the discharge time (*see 11*), and
- h) Record concentration readings and holding times (*see 11*).

C-6 RECOMMISSIONING

Restore all systems to a fully operational status.

C-7 REPORTING

The following shall be reported:

- a) 1) installation, designer and contractor;
2) enclosure identification;
3) enclosure temperature prior to discharge;
4) design concentration; and
5) position of sampling points.
- b) Date and time of test,
- c) Discharge time,
- d) Concentrations at each sampling point at 1 and 10 min from the commencement of discharge, and
- e) System deficiencies.

Cross-check various observed parameters with the respective operating clauses are in conformity therewith.

ANNEX D

(Clause 10.10)

REQUIREMENTS FOR TESTING ENCLOSURE INTEGRITY

D-1 TEST FOR DETERMINATION OF PREDICTED MINIMUM HOLD TIME

D-1.1 Principle

A fan is temporarily located within an access opening to pressurize and depressurize the enclosure. A series of pressure and air flow measurements is made from which the leakage characteristics of the enclosure; are established.

The predicted hold time is calculated using these leakage characteristics on the following assumptions:

- a) That leakage occurs under the worst conditions, that is, when one-half of the effective leakage area is at the maximum enclosure height and represents the inward leakage of air, and the other half (the lower leakage area) of the total effective leakage area is at the lowest point in the enclosure and represents the outward leakage of extinguishant/air,
- b) That all leak flow is one-dimensional, i.e. ignoring stream functions,
- c) That flow through any particular leak area is either into or out of the enclosure and either from or into an infinitely large space,
- d) That the system is at sea-level, at a temperature of 20°C, and atmospheric pressure of 1.013 bar absolute, and
- e) An enclosure integrity test is deemed successful when at least 80 percent of the design concentration is available within the enclosure at the expiry of 10 min (*see D-2.10*).

D-1.2 Apparatus

- a) Fan unit, consisting of a frame which will fit into and seal an access opening in the enclosure, and one or more variable speed fans, with low flow facilities, capable of giving a differential pressure of not less than 25 Pa across the enclosure boundary,
- b) Two pressure-measuring devices, one to measure enclosure differential pressure and one to measure fan flow pressure,
- c) Flexible tubing, for connecting the pressure-measuring devices,
- d) Chemical smoke pencils and/or smoke generator,

- e) Two thermometers, to measure ambient temperatures, and
- f) Signs, reading "DO NOT OPEN — PRESSURE TEST IN PROGRESS" and "DO NOT CLOSE — PRESSURE TEST IN PROGRESS".

NOTE — Additional apparatus, such as measuring tapes, torches, ladders, tools to remove floor and ceiling tiles, computer or other calculating device, may be necessary.

D-1.3 Calibration of Apparatus

- a) *Fan Unit* — Calibrate the fan unit at the intervals and by the method recommended by the manufacturer. Keep records and, where appropriate, calibration certificates. Use a flow meter accurate to ± 5 percent and a pressure-measuring device accurate to ± 1 Pa.
- b) *Pressure-Measuring Devices* — The pressure-measuring devices shall be calibrated not more than 12 months before a test. Records shall be maintained and, where appropriate, calibration certificates. If inclined manometers are used, change the fluid not more than 3 months before the test. Level and zero inclined manometers before each test.

D-1.4 Preliminary Preparation

- a) Obtain a description from the user of the air-handling equipment and extinguishant-extraction systems in the enclosure,
- b) Check for the following:
 - 1) raised platform floors and false ceiling spaces;
 - 2) visually obvious leaks in the enclosure;
 - 3) adequate return paths outside the enclosure between all leaks and the fan unit; and
 - 4) conflicting activities in and around the enclosure.
- c) Provide the following information to the user:
 - 1) a description of the test;
 - 2) the time required to complete the test;
 - 3) what assistance will be needed from the user's staff; and
 - 4) Information on any necessary disturbance to the building or its services during the test (for example,

removal of floor or ceiling tiles, shutdown of air-handling systems, holding doors open and/or shut).

D-1.5 Evaluation of Enclosure

Obtain or prepare a sketch plan showing the walls, the location of the door and other openings through which air will flow during the test, and the location of any ducts penetrating the enclosure, and any dampers in the ducts. Show the status (that is, whether open or closed when the extinguishant system is discharged) of each door, hatch and damper, and which access opening(s) is (are) to be used for the fan unit.

Show the location of floor and sink drains.

D-1.6 Measurement of Enclosure

Measure the protected enclosure volume as necessary and record the following:

- a) Overall height of the protected enclosure,
- b) Height of the highest hazard in the enclosure, and
- c) Gross volume of the protected enclosure.

D-1.7 Test Procedure

a) Preparation for Test

- 1) Advise supervisory personnel in the area of the test.
- 2) Remove papers and objects likely to be disturbed by the turbulence from the fan.
- 3) Block open sufficient doors outside the enclosure envelope to provide an adequate return path for air between the fan unit and the enclosure leaks, while correcting any breach of any requirements of the facility, including requirements for security, fire protection and environmental boundaries.
- 4) Using the sketch plan (*see D-1.5*), set all air-handling equipment and extinguishant-extraction systems to the state they would be in at the time of extinguishant system discharge, except for the following:
 - i) Recirculating air-handling equipment without fresh air make-up which does not give a bias pressure across the enclosure boundary or otherwise preclude accurate testing, and which would be shut down on extinguishant discharge, may be left operating

during the test if this is needed to avoid temperature build-up in equipment such as computers; and

- ii) Recirculating air-handling equipment which would continue to operate on extinguishant discharge should be shut down, if it creates excessive bias pressure.
- 5) Post the appropriate signs on doors [*see D-1.2 (f)*].
- 6) Open doors and remove floor or ceiling tiles within the extinguishant-protected portions of the enclosure envelope so that the extinguishant-protected volume is treated as one space. Do not remove false ceiling tiles if the volume above the false ceiling is not protected with extinguishant.
- 7) Close all doors and windows in the enclosure envelope.
- 8) Check that liquid traps in the floor and sink drains are sealed with liquid.
- b) *Setting up Door Fan Unit*
 - 1) Set up the fan unit in an access opening leading from the enclosure into the largest volume of building space which will complete the air-flow path from the fan, via the enclosure, leaks and building space back to the fan.
 - 2) Gently blow into or suck from the flexible tubing so that the readings of the pressure-measuring devices traverse the full scale. Hold the maximum reading for not less than 10 s. Release the pressure and zero the devices.
 - 3) Connect the enclosure differential pressure-measuring device. Ensure that the open ends of the flexible tubing near the fan unit are away from its air stream path and any other air flows which might affect the readings.
 - 4) Use the fan(s) to raise or lower the pressure of the enclosure by approximately 15 Pa. Check all dampers with smoke and ensure that they are closing properly. Check doors and hatches and ensure correct closure. Inspect the wall perimeter (above and below any false floor) and the floor slab for any major leaks and note their size and location.

c) *Measurement of Bias Pressure*

- 1) Seal the fan unit inlet or outlet and, without the fan(s) operating, observe the enclosure differential pressure-measuring device for at least 30 s.
- 2) If a bias pressure is indicated, use smoke to detect the consequent air flow and its direction. If the existence of a bias pressure is confirmed, record the pressure-measuring device reading as the bias pressure (P_b).
- 3) If the enclosure is large, or if the bias pressure is largely caused by wind or stack effects, repeat the measurement at one or more different access openings. Record all the values measured and use the largest positive value (or if only negative values are recorded, the value closest to zero) as the bias pressure.

A bias pressure as low as 0.5 Pa can affect the accuracy of the test result. If the bias pressure has a numerical value greater than 25 percent of fire extinguishant/air column pressure, then the hold time is likely to be low and the enclosure may not hold the specified extinguishant concentration. The source of the excessive bias pressure should be identified and, if possible, permanently reduced.

In the event of fluctuating bias pressures (such as those created by wind effects), it may not be possible to achieve the necessary correlation accuracy in the fan test results. These fluctuating pressures may need to be eliminated before an accurate fan test can be carried out.

d) *Measurement of Leakage Rate*

- 1) Measure the air temperature inside the enclosure, T_e , and measure the air temperature outside the enclosure T_o , at several points. If the location of leaks is not known, use the average value; otherwise, use the average value weighed according to the known location of the leaks.
- 2) Unseal the fan inlet or outlet and connect the fan flow pressure-measuring device.
- 3) Use the fan unit to depressurize the enclosure to the maximum extent, but by not more than 60 Pa. Allow the enclosure differential pressure measuring reading to stabilize (which may take up to 30 s) and record the value ($P_f + P_b$) which will be negative. Repeat at not less than four more fan unit flow rates to give five readings more

or less evenly spaced over the range down to 10 Pa.

- 4) Use the fan unit to pressurize the enclosure and repeat the procedure of (d) (iii). Again record the value of ($P_f + P_b$), which will be positive.

NOTE — For calculation purpose, either P_f or P_b or the average of the two can be taken.

D-2 CALCULATIONS

D-2.1 Notations

Q	= air leakage rate, in m^3/s ;
C	= flow coefficient;
P	= pressure within enclosure, in Pa;
N	= slope of the graph;
R_M	= density of agent /air Mixture, in kg/m^3 ;
Agent	Density, kg/m^3
Air	1.202
HCFC Blend A	3.84
HFC-227ea	7.26
IG-541	1.41
IG-55	1.41
R_A	= density of air, in kg/m^3 ;
R_G	= density of agent, in kg/m^3 ;
P_M	= agent/Air column pressure, in Pascal (Pa);
G	= gravitational acceleration, $9.81 \text{ m}/\text{s}^2$;
H_o	= total height of the enclosure, in m;
H	= minimum acceptable height in the enclosure, in m;
A	= area of the enclosure, in m^2 ;
V	= volume of the enclosure, in m^3 ;
Q_m	= uncorrected agent/air mixture leakage rate, in m^3/s ;
Q_M	= corrected agent/air mixture leakage rate, in m^3/s ;
T_L	= temperature within the enclosure, in $^{\circ}\text{C}$;
T_F	= temperature outside the enclosure, in $^{\circ}\text{C}$;
ELA	= equivalent leakage area, in m^2 ;
K	= discharge coefficient (0.61 to 1 depending upon nature of leakage openings);
γLA	= total leakage area, in m^2 ;
LLF	= lower leak fraction;
ALL	= area of lower leaks, in m^2 ;
c	= agent concentration, in percent;

C_p = pass concentration in percent (80 percent of the design agent concentration);

C_3 = equation simplification constant;

C_4 = equation simplification constant; and

T = retention time of pass concentration (C_p) within the enclosure, in seconds.

D-2.2 After pressurizing (depressurizing) the enclosure to various pressures, corresponding flow rates in l/s for each room pressure shall be recorded wherefrom the flow at 1 Pa pressure is determined. This value (C) is deemed as flow coefficient (constant) for the purpose of calculation.

The formula establishing a relation between flow and the pressure is $Q = CP^N$ where Q = Air leakage rate, in m^3/s , C = Flow coefficient, P = Pressure within enclosure in Pa and N = Slope of the graph.

NOTE — The value of N can be determined by substituting observed values for Q , P and C in the above equation.

D-2.3 The next step will be to determine the density of agent/air mixture (R_M):

$$RM = \frac{(RG)(c)}{100} + \frac{(RA)(100-c)}{100} \text{ kg/m}^3$$

D-2.4 The next step will be to determine the agent/air column pressure (PM):

$$P_M = (G)(H_o)(R_M - R_A) Pa$$

D-2.5 The next step will be to determine the uncorrected agent/air mixture leakage rate:

$$Q_m = (C)(P_M)^N m^3/s$$

D-2.6 The next step will be to determine the corrected

agent/air mixture leakage rate:

$$Q_M = \frac{(Q_m)(T_L + 273)}{(T_p + 273)} m^3/s$$

D-2.7 The next step will be to determine the equivalent leakage area (ELA):

$$ELA = \frac{(1.271)(Q_M)}{\sqrt{P_M}} m^2$$

D-2.8 The next step will be to determine the total leakage area (TLA):

$$TLA = (K)(ELA) m^2$$

D-2.9 The next step will be to determine the lower leak fraction (LLF):

$$LLF = \frac{ALL}{TLA}$$

D-2.10 The next step will be to determine the retention time (T):

$$T = \frac{(A)[(C_3 H_o + C_4)^{(1-N)} - (C_3 H + C_4)^{(1-N)}]}{(1-N)(C_3)(LLF)(TLA)} s$$

where

$$C_3 = \frac{(2G)(R_M - R_A)}{(R_M) + (R_A) \left[\frac{LLF}{1 - LLF} \right]^{1/N}}$$

$$C_4 = \frac{2(\text{Static pressure inside enclosure})}{R_M}$$

NOTES

- 1 If static pressure is negative, then treat it as zero.
- 2 If static pressure is positive, then consider actual value.

ANNEX E

(Clause 11.8.3)

INFORMATION ON TWO-PHASE FLOW FOR LIQUEFIED HALOCARBON GASES

E-1 As the extinguishant in the liquid phase flows from the storage container, the pressure drops or recedes. The pressure recession varies with container fill density. It is assumed that there was thermodynamic equilibrium between the liquid and vapour phases in the storage container. In actual tests, it has been noted that there is a sharp drop in pressure during the initial rush of liquid into the distribution system. This is due to a lag between the pressure drop and the onset of boiling in the container. As boiling commences, the pressure returns to the pressures shown on the curves for respective gaseous extinguishants representing the calculated pressure in the storage container versus the percentage discharge of extinguishant from the container for both 2.5 MPa and 4.2 MPa systems.

E-2 AGENT IN PIPE WORK

Agent flows through the distribution system in both liquid and vapour phase. As the liquid phase flows through the distribution system the pressure continues to drop, causing the liquid to boil. The volume of the vapour phase increases with the decreasing pressure and hence the density of the mixture drops. To maintain a constant flow rate, the speed through the distribution system must continuously increase down the pipe work. The pressure drop for a given flow rate is not linear, as it is with water, but is variable along the pipe.

E-3 DENSITY OF AGENT IN DISTRIBUTION SYSTEM

Using the thermodynamic properties of the Agent, including the nitrogen used for super-pressurization, the density of the two-phase mixture in the distribution system can be calculated. The density of the Agent leaving the storage container varies over the course of the discharge. The density is lowest at the start of discharge and increases until the last of the liquid leaves the container.

E-4 TEMPERATURE

The drop in container pressure as the Agent flows from the container causes remaining Agent in the container to cool. As a result, liquid that is below ambient temperature is introduced to the distribution system. During a system discharge the temperature of the Agent leaving the storage container recedes as a function of instantaneous container pressure.

E-5 INITIAL VAPOUR TIME

At the start of discharge virtually all the liquid phase

Agent entering the distribution system is vaporized before it reaches the nozzles, due to heating by the pipe work and the initial low pressure in the system. The initial vaporization limits the flow of Agent through the distribution system because the mass flow of vapour is much lower than that of liquid.

E-6 LIQUID FLOW

There is a significant delay between the opening of the discharge valve and the first appearance of liquid at the nozzles. Some of the delay is due to the flow restriction presented by the container and distribution system, however much of delay is due to the initial vapour phase flow of the Agent.

E-7 PHASE SEPARATION

The flow of Agent in the distribution system is a two-phase flow (containing both liquid and vapour). In a properly sized distribution system the flow will be highly turbulent throughout the system and the two phases will mix homogeneously. If the pipes are too big the phases may tend to separate, which can cause a variety of flow problems and can in some cases result in a reduced flow rate.

E-8 AVERAGE PRESSURE CONDITIONS

Pressure at the nozzle is not constant throughout discharge because the pressure in the storage container is constantly decreasing. If one were to attempt manual calculation it would be desirable to use an average pressure condition. It is difficult to arrive at an average as the volume of piping has a marked effect on the average nozzle (pressure, density and velocity conditions), all of which, have a marked effect on discharge quantities and times.

E-9 AVERAGE NOZZLE PRESSURE

The nozzle pressure used for calculations is the pressure when half the liquid phase has been discharged from the nozzle. The timing of this is used to calculate an average pressure drop in the distribution system. To calculate the correct storage container pressure, allowance must be made for the amount of liquid in the piping system.

E-10 PERCENT IN DISTRIBUTION SYSTEM

The points outlined above are taken into consideration to calculate the average container pressure during discharge. The ratio of the pipe volume to the volume of Agent supply expanded under flowing conditions varies with average container pressure. The former quantity shall be referred to as percent-in-the-pipe.

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